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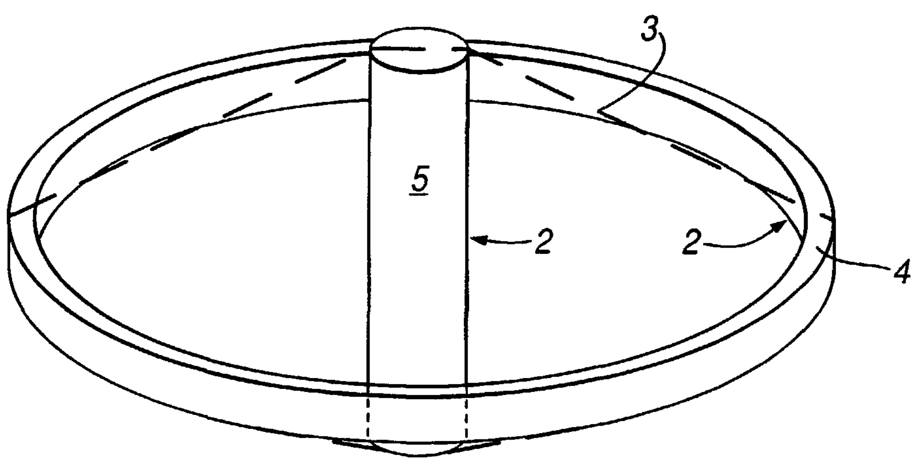
(54) Title: STIFFENED MEMBRANE ASSEMBLIES



(57) Abstract: A stiffened membrane assembly for use as the diaphragm of a loudspeaker drive unit or as a wall of a loudspeaker enclosure comprises a frame (2) and a multiplicity of tensile members (3) spanning the frame (2) and acting in tension on it, the frame and tensile members having a membrane attached thereto.

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Stiffened membrane assemblies

It is well known to hi fi experts that the quality of sound produced by a loudspeaker system comprising a loudspeaker drive unit mounted in an loudspeaker enclosure is invariably influenced to a greater or lesser extent by resonance phenomena in the drive unit and the enclosure.

Resonance in the diaphragm of the loudspeaker drive unit or in the walls of the enclosure can be made less objectionable by arranging that the resonance frequency shall be very high. The resonance frequency can be made higher by increasing the stiffness of the parts in question.

As long ago as 1930, it was proposed to stiffen the diaphragm of a loudspeaker drive unit by providing spring wires to tauten the membrane between its base and apex (see patent specification GB 0 335 329). More recently (see European patent specification EP 0 330 423), it has been proposed to make the diaphragm of a loudspeaker drive unit out of rubber and to maintain it under permanent tension by means of a spring acting on the centre of the diaphragm.

Such proposals are simply too feeble in action to impart any very great stiffness to the diaphragm.

European patent specification 0 191 595 discloses how the wall of a loudspeaker enclosure can be stiffened using first and second sets of intersecting stiffening panels within the enclosure. Such an arrangement is capable of excellent results but unfortunately tends to be rather expensive to manufacture.

It is an object of the invention to provide a means of stiffening either the diaphragm of a loudspeaker drive unit or the walls of a loudspeaker enclosure which is capable of being both highly effective and not overly expensive to manufacture.

The present invention provides a stiffened membrane assembly for use as the diaphragm of a loudspeaker drive unit or as a wall of a loudspeaker enclosure, the assembly comprising a frame and a multiplicity of tensile members spanning the frame and acting in tension on it, the frame and tensile members having a membrane attached thereto.

In such a construction, very high tensile forces can be employed to create pre-stressing and make the assembly very rigid so that it has very advantageous properties for use in a loudspeaker drive unit or a loudspeaker enclosure. The initial pre-stressing should, of course, exceed any stresses experienced during normal use. When tens or hundreds of tensile members are provided, the aggregate tensile force can be extremely large even when the tension of any one tensile member considered alone is only moderate.

Pre-stressing may be achieved by chemical means, temperature means, for example, making while cold and heating up to produce the required stress or **vice versa,** by piezo-electric means, for example, by an outer ring or an inner hub or both iin the form of a piezo electric bimorph which expands when a voltage is present so creating the required pre-stress, by magnetic means, by electrostatic means, by electromagnetic means, by biological means, for example, by manufacture from synthetic muscle fibres or an analogue of thereof, by magneto-strictive means, by taking the material of the diaphragm past its Hooke's law limit by various means and then releasing it, or by work hardening techniques

For a diaphragm for a loudspeaker drive unit, the membrane may be a skin laid over and/or bonded to tensile members in the form of stretched fibres or rods, which skin seals the surface, moves the air, does the sound radiating, and prevents air and sound from the rear of the loudspeaker drive unit from reaching the front thereof.

The skin may be plastics or metal foil or sheeting, an air tight film of glue, sealant or damping compound. It should not bend significantly from tensile member to tensile member, although that is less significant the more spokes or fibres there are as the unsupported regions then become smaller and smaller. The skin, if strong enough, may also be used to enhance and/or replace the function of the tensile members as well. A stressed film or films made of metal, composite materials, ceramics or plastics in tension may be arranged between a hub and a rim, or between opposing sides of the frame which may have virtually any outer profile.

Membranes in the form of airtight skins may be used. The airtight skins may be filled with air at a pressure greater than atmospheric thus forcing the skins to bow outwards and become stressed as a result. The airtight skins may be evacuated thus forcing the skins to bow inwards and become stressed as a result. The airtight skins may be both pre-stressed and evacuated. The airtight skins may be both pre-stressed and pumped up to positive air pressure.

An additional, cylindrical reinforcing member, made of metals plastics, wood or any composite material, may be placed at a suitable radius from a central member. Indeed, additional reinforcing members may be placed at various radii in the manner of fabric aeroplane wings. Thus producing a series of shorter rods or fibres or sections of the skin in tension in between the reinforcing members.

Advantageously, the tensile members comprise flexible material stretched across the frame. That construction provides a simple means of generating very high tensile forces.

The tensile members may comprise tensioned fibres for example, Kevlar, nylon, carbon fibre, or virtually any other man made or natural fibre.

Advantageously, at least one length of the flexible material is wrapped repeatedly around the frame. That again provides a simple means of generating very high tensile forces.

The tensile members preferably comprise cord made of plastics material filaments. Such cord has very great tensile strength.

Advantageously, the cord is made of Kevlar (registered Trade Mark). Kevlar is a material possessing very great tensile strength.

Preferably, the membrane is bonded to the tensile members. That provides a simple means of ensuring that the rigidity of the frame and tensile members is communicated to the membrane.

The frame may be generally flat and square or rectangular in outline and a respective membrane may be provided at each of the two opposite faces of the frame. Such a construction is suitable for making a wall of a loudspeaker enclosure.

The frame may be circular in outline and a membrane may be provided at one face of the frame only. Such a construction is suitable for making a diaphragm for a loudspeaker drive unit.

Advantageously, the frame comprises an integrally-formed closed loop of material. Such a construction can be subjected to a high degree of compression by the tensile forces of the tensile members acting on it.

Preferably, the closed loop of material is made of carbon fibre. A very high strength to weight ratio can be obtained in that way.

Advantageously, the frame comprises an outer member and an inner member, and the tensile members act in tension on both the inner member and the outer member. Such a construction is capable of providing the strength and rigidity possessed by the type of construction employed in a bicycle wheel.

In particular, one can use a ring-shaped rim, much like a bicycle tyre, but made of a very strong and rigid material such as carbon fibre and which is resistant to compressive stresses. It may be solid, preferably a hollow toroid, a U-shaped channel facing inwards outwards or in virtually any direction. Otherwise, it may have virtually any other profile and may be made of metal, ceramics, fibres or composite materials.

Wheel-type constructions, particularly those involving stressed spoke constructions, are incredibly rigid, bearing in mind the amount of material present. This rigidity comes about **via** a process of matching the tension stresses in the spokes against the resulting compression stresses in the rim. An analogous process is here applied to the construction of loudspeaker diaphragms and to the construction of walls of loudspeaker enclosures. For driver diaphragms, the most logical construction is one with a circular outer profile and a hub at the centre. For enclosure walls, the most logical construction is a square, oblong or other symmetrical shape with stiff outer members and a stressed skin and/or spokes between opposing sides.

The tensile members may, in effect, be a multiplicity of spokes, resistant to tensile stresses, made of materials such as Kevlar or individual carbon fibres or rods of composite materials, metals alloys or ceramics. The fibres or rods making up these spokes, may be "limp" to bending stresses, unlike bicycle wheel spokes, or they may be stiff to bending stresses as are bicycle spokes, but should be resistant to stretching arising from pre-tension in both cases. The spokes may be rods or fibres of metal composite materials, plastics or ceramics in tension between opposing sides of the construction, which may have virtually any outer profile, covered with a membrane which may be a plastic or metal film or a film of a glue sealant or damping compound.

Thus, a loudspeaker diaphragm having the same mass as a conventional diaphragm, but with higher break up modal frequencies and potentially having a flatter shape can be made according to the invention by utilising a variant of a pre-stressed wheel construction, the essential extra feature of which over conventional cone construction is tensile "prestress" in the spokes, the diaphragm or the enclosure wall.

A pre-stressed wheel consists of the following parts: (1) a rim which is in compression owing to (2) a multiplicity of spokes, usually rods of metal, which are in tension, and (3) a hub which is in outward tension owing to the pulling forces arising from the tension in the spokes, and which is also in axial compression owing to the same forces.

The frame may comprise an outer rim member defining the closed loop and an inner hub member. Such a construction is very strong and simple.

The axial dimension of the hub member may be larger than the axial dimension of the rim member, thus forcing the overall construction of spokes plus membrane, hub member and rim member to have a triangular cross section . The overall shape looking very much like a conventional bicycle wheel.

The hub member may have the same axial dimension as the rim thus forcing the spokes and diaphragm to have an oblong cross section where the upper and lower surfaces of spokes plus membrane are parallel. The overall shape looking like a flat disc.

The rim member may have a larger axial dimension than the hub member thus forcing the overall construction to have a triangular cross section . The overall shape looking like a disk with a concave upper and lower surface.

The inner hub member, to which a voice coil is attached when making a diaphragm for a loudspeaker drive unit, should be resistant to compressive stresses and buckling stresses in the axial direction and tearing stresses in the outwards direction. The hub member may be made of virtually any material which is resistant to compressive and bucking stresses such as metals, composite materials and ceramics.

Advantageously, the inner hub member projects from two opposite sides of the outer rim member and the tensile members define a respective conical surface on each side of the frame, a membrane being provided on just one of the conical surfaces. Such a construction provides a simple means of providing a conical diaphragm for a loudspeaker drive unit.

Preferably, the inner hub member is circular in plan and the tensile members lie substantially tangential to it. Such an arrangement has the advantages that it easy to produce using a winding machine and also leaves the ends of inner hub member free. A continuous cord may be wound round and round the outer member either (1) returning on each turn on the same side of the inner hub member with a gradual progression about the inner hub member on each turn, or (2) returning on each turn on the opposite side of the inner hub member, again progressing around the inner hub member. The latter winding scheme is preferred as being more stable than the former, particularly in the case of assemblies of small or moderate size.

Advantageously, the inner hub member includes first and second flange members spaced apart along the axis of the inner hub member which the tensile members engage. Such an arrangement provides a simple way of mounting the tensile members on the inner hub member and is well suited to winding of a continuous cord using a winding machine.

Preferably, the tensile members engage the first and second flange members on the axially outer sides thereof. Such an arrangement is easy to wind and suited to making a winding of a "<>" shape in section suitable for making a diaphragm of a loudspeaker drive unit. Instead, it is possible, however, to engage the first and second flange members on the axially inner sides thereof when it is desired to make a winding of a "><" shape in section.

Advantageously, the tension in the tensile members arises, at least in part, from a prior forcible displacement, and subsequent fixing in position, relative to one other of two components on which the tensile members are located. Very high values of tension can be achieved by that means, particularly as an initial tension created by the use of a winding machine can be supplemented by the forced displacement tensioning.

The said two components subjected to forcible displacement may be the said first and second flange members. One or both of the flange members may be mounted movably on the inner hub member, subsequently forced into a new position against the tension of the tensile members, and then secured in position, for example, by means of a suitable adhesive. The or each flange member may include a specially shaped portion, such as a projecting collar, to facilitate the obtaining of a purchase upon the flange member for its forcible displacement.

The invention also provides a loudspeaker drive unit having an assembly as claimed in any preceding claim constituting its diaphragm.

The invention also provides a loudspeaker enclosure having an assembly as claimed in any preceding claim constituting at least one wall thereof.

Ways of carrying out the invention will now be described with reference to the accompanying drawings, in which:

Figure 1 is a perspective view of a partially completed diaphragm for a loudspeaker drive unit;

Figure 2 is a diagrammatic part-sectional side view of the construction of Figure 1;

Figure 3 is a diagrammatic view of a partially completed wall for a loudspeaker enclosure;

Figure 4 is a diagrammatic illustration of one form of tangential winding for an assembly according to the invention;

Figure 5 is a cross-sectional view of a loudspeaker drive unit incorporating a tangentially wound assembly according to the invention; and

Figure 6 is partially cut-away front elevation of the loudspeaker drive unit according to Figure 5.

Referring to the accompanying drawings, Figure 1 shows a partially completed stiffened membrane assembly 1 for use as the diaphragm of a loudspeaker drive unit. The assembly 1 comprises a frame 2 and a multiplicity of tensile members 3 spanning the frame and acting in tension on it, the frame and tensile members having a membrane (not shown) attached thereto.

The tensile members 3 comprise flexible material stretched across the frame, the flexible material being cord made of Kevlar (registered Trade Mark) plastics material filaments. A single length of the Kevlar cord is wrapped, under tension, repeatedly around the frame, although only a single turn is shown in the drawings.

The frame 2 comprises (i) an integrally-formed closed loop of material 4 in the form of an annulus made of carbon fibre, the annulus defining an outer rim member, and (ii) an inner hub member 5 in the form of an aluminium cylinder projecting from two opposite sides of the outer rim member 4. The tensile members 3 act in tension on both the inner member and the outer member.

The tensile members 3 define a respective conical surface on each side of the frame by virtue of the fact that the Kevlar cord is wound round and round the frame whilst shifting a small angular position around the annulus with each turn. Each turn of the cord can, for example, be spaced two millimetres apart from an adjacent turn on the circumference of the annulus. A loudspeaker drive unit of 250 millimetres diameter would thus have about 400 turns with that spacing of the Kevlar cord. The ends of the Kevlar cord are secured, for example, by adhesive bonding to the hub member 5.

To complete the assembly, a membrane (not shown) to constitute the actual diaphragm is provided on just one of the conical surfaces by bonding it to the tensile members. A voice coil (not shown) is added to the end of the hub member 5 provided with the membrane.

Such a construction can be employed in various sizes of loudspeaker drive unit, for example, in a tweeter with a diameter for the annulus in the range ¼" to 2", in a mid-range speaker with a diameter for the annulus in the range 1" to 12", and in a bass speaker with a diameter for the annulus in the range 2" to 33". In some

instances, the hub member 5 can be given a diameter in the range ½" to 5", or ¾" to 4", or 1" to 2" for use with a voice coil of corresponding diameter.

Figure 3 shows a partially completed wall 20 for a loudspeaker comprising a frame 22, generally flat and rectangular in outline, with Kevlar cord 24 wound, under tension, round and round about it. Only a few turns of the Kevlar cord are indicated in the drawings and the remainder are indicated by a broken line. A respective membrane (not shown) is provided at each of the two opposite faces of the frame and bonded to the Kevlar cord.

Figure 4 illustrates the winding of a Kevlar cord 34 by a tangential technique. A circular inner hub member is represented in Figure 4 by the circle 30 and an outer member by the circle 32. The cord 34 first passes as a tangent, marked **a**, to the circle 30 on one side thereof, and the cord then returns as a tangent, marked **b** and shown as a broken line, on the opposite side of the circle 30. The cord 34 then passes across as the tangent **c** and returns on the opposite side as tangent **d**. Further tangents **e f g h i** and so on are created likewise until the winding is completed.

Figure 5 shows a cross-section through a loudspeaker drive unit incorporating an assembly wound by the tangential technique just described. The assembly comprises a circular inner hub member 40 in the form of a carbon fibre ring. First and second flange members 42 and 44 are spaced apart along the axis of the inner hub member and are engaged by the Kevlar cord 46. An outer rim member 47 in the form of a carbon fibre ring forms the outer part of the frame on which the Kevlar cord 46 is wound. A membrane 43 secured to the Kevlar cord 46 to constitute the diaphragm of the loudspeaker drive unit and an end cap 41 for the inner hub member 40 are omitted from Figure 5 for ease of illustration but are to be seen in Figure 6.

As shown in Figure 5, the Kevlar cord 46 engages the first and second flange members 42, 44 on the axially outer sides thereof, the winding thus being "<>" shaped as seen in the sectional view.

The tension in the Kevlar cord 46 is achieved by forcible displacement, and subsequent fixing in position, relative to one other of the first and second flange members 42 and 44.

Figure 5 also shows how the assembly according to the invention is used with conventional loudspeaker drive unit components comprising a surround 48, a chassis 50, a voice coil 52, a suspension and spacer 54, and a magnet assembly 56.

Many variations to the illustrated embodiments are possible within the scope of the invention defined by the appended claims.

If desired, the frame and Kevlar cord could be pre-stressed by stringing the frame with the cord analogously to the stringing of a tennis racquet.

he tensile members can be put into tension wholly or partly by making the frame in an expansible form and expanding it against the tensile members. For example, the hub member can be made in two or more parts to provide a telescopic construction and then forcibly extended against the Kevlar cord. After the forcible extension, the extended hub member is held in position by pinning, securing by adhesive, riveting or other means.

Instead of attaching the voice coil to the hub member, it can be attached to the annulus to make a loudspeaker drive unit of the "dome" type where the voice coil diameter corresponds to the diameter of the diaphragm.

It is also possible to make a loudspeaker drive unit in which two membranes applied to respective sides of an annular frame with the multiplicity of tensile members are inflated like a balloon and have a voice coil attached to the equator, as it

were, of the balloon. Such a construction can be used, in particular, for making a tweeter or even a mid-range loudspeaker drive unit.

CLAIMS:

1. A stiffened membrane assembly for use as the diaphragm of a loudspeaker drive unit or as a wall of a loudspeaker enclosure, the assembly comprising a frame and a multiplicity of tensile members spanning the frame and acting in tension on it, the frame and tensile members having a membrane attached thereto.

2. An assembly as claimed in claim 1, wherein the tensile members comprise flexible material stretched across the frame.

3. An assembly as claimed in claim 2, wherein at least one length of the flexible material is wrapped repeatedly around the frame.

4. An assembly as claimed in any preceding claim, wherein the tensile members comprise cord made of plastics material filaments.

5. An assembly as claimed in claim 4, wherein the cord is made of Kevlar.

6. An assembly as claimed in any preceding claim, wherein the membrane is bonded to the tensile members.

7. An assembly as claimed in any preceding claim, wherein the frame is generally flat and square or rectangular in outline and a respective membrane is provided at each of the two opposite faces of the frame.

8. An assembly as claimed in any preceding claim, wherein the frame is circular in outline and a membrane is provided at one face of the frame only.

9. An assembly as claimed in any preceding claim, wherein the frame comprises an integrally-formed closed loop of material.

10. An assembly as claimed in any preceding claim, wherein the closed loop of material is made of carbon fibre.

11. An assembly as claimed in any preceding claim, wherein the frame comprises an outer member and an inner member, and the tensile members act in tension on both the inner member and the outer member.

12. An assembly as claimed in claim 11 when dependent on claim 9 or claim 10, wherein the frame comprises an outer rim member defining the closed loop and an inner hub member.

13. An assembly as claimed in claim 12, wherein the inner hub member projects from two opposite sides of the outer rim member and the tensile members define a respective conical surface on each side of the frame, a membrane being provided on just one of the conical surfaces.

14. An assembly as claimed in claim 12 or claim 13, wherein the inner hub member is circular in plan and the tensile members lie substantially tangential to it.

15. An assembly as claimed in claim 14, wherein the inner hub member includes first and second flange members spaced apart along the axis of the inner hub member which the tensile members engage.

16. An assembly as claimed in claim 15, wherein the tensile members engage the first and second flange members on the axially outer sides thereof.

17. An assembly as claimed in any preceding claim, wherein the tension in the tensile members arises, at least in part, from a prior forcible displacement, and subsequent fixing in position, relative to one other of two components on which the tensile members are located.

18. An assembly as claimed in claim 17 when dependent on claim 15 or claim 16, wherein the said two components are the said first and second flange members.

19. A stiffened membrane assembly substantially as herein described with reference to, and as illustrated by Figures 1 and 2 of the accompanying drawings.

20. A stiffened membrane assembly substantially as herein described with reference to, and as illustrated by Figures 4, 5 and 6 of the accompanying drawings.

21. A loudspeaker drive unit having an assembly as claimed in any preceding claim constituting its diaphragm.

22. A stiffened membrane assembly substantially as herein described with reference to, and as illustrated by Figure 3 of the accompanying drawings.

23. A loudspeaker enclosure having an assembly as claimed in any of claims 1 to 18 or claim 22 constituting at least one wall thereof.

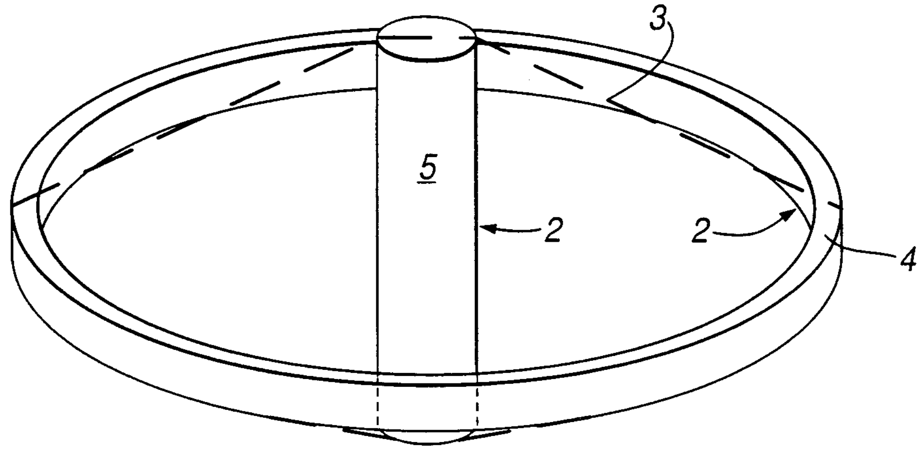

Fig.1

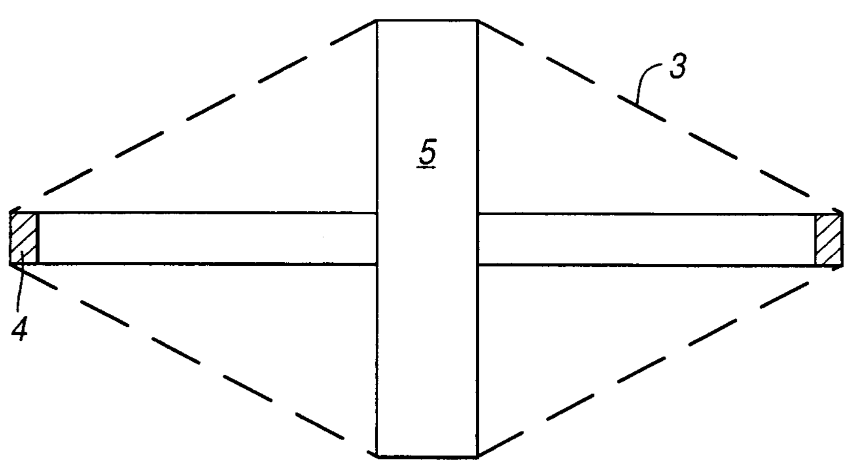

Fig.2

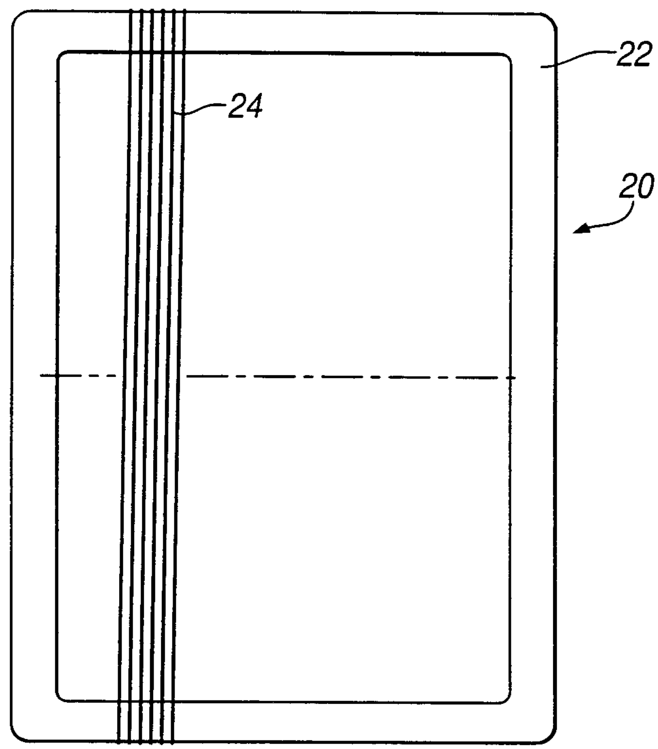

Fig.3

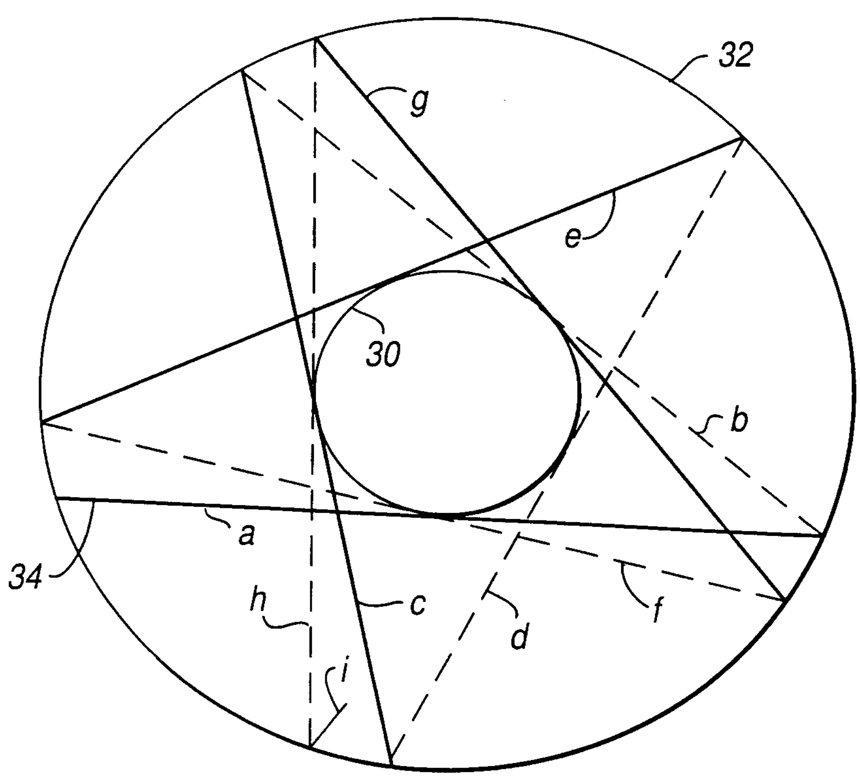

Fig.4

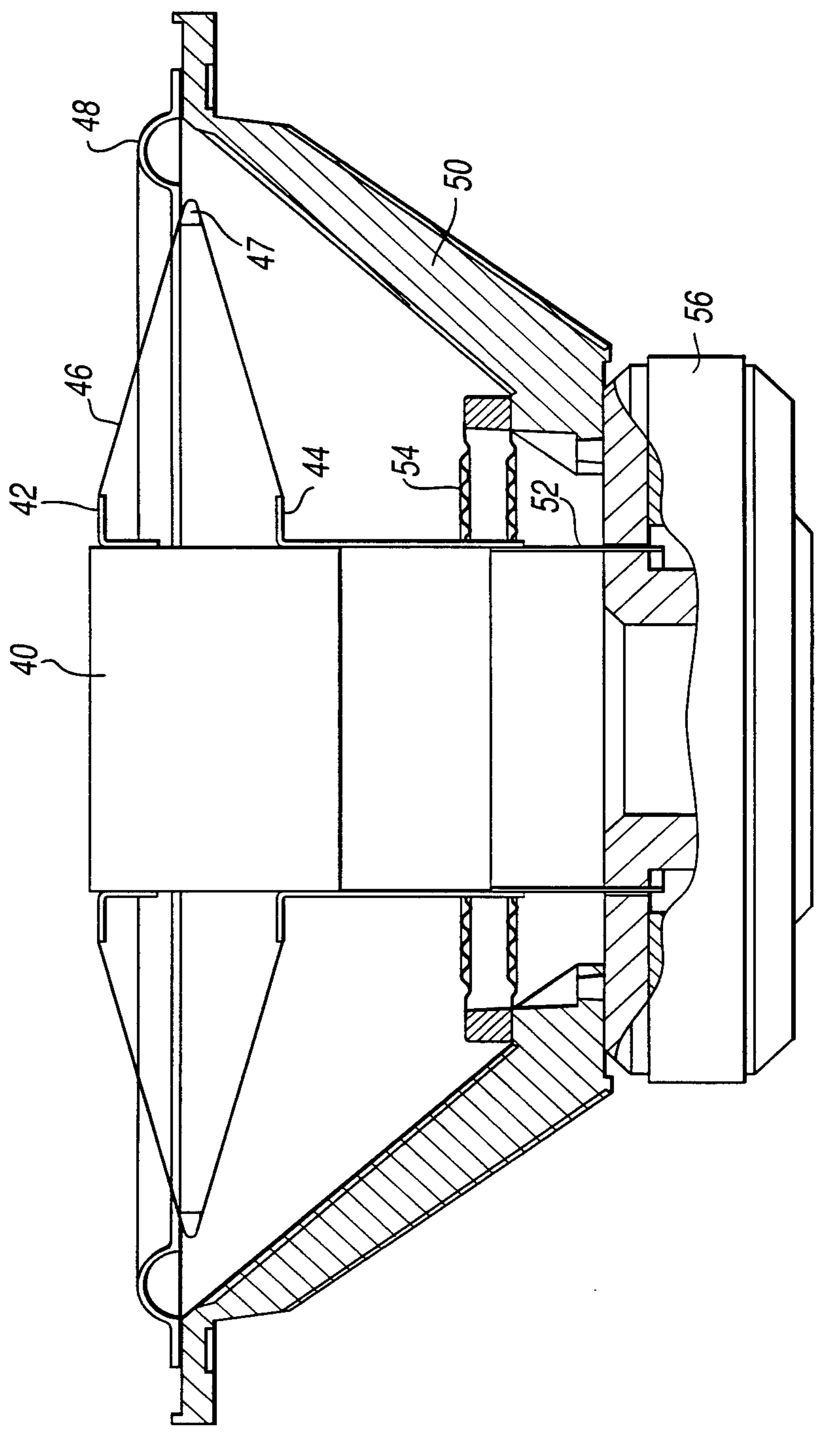

Fig.5

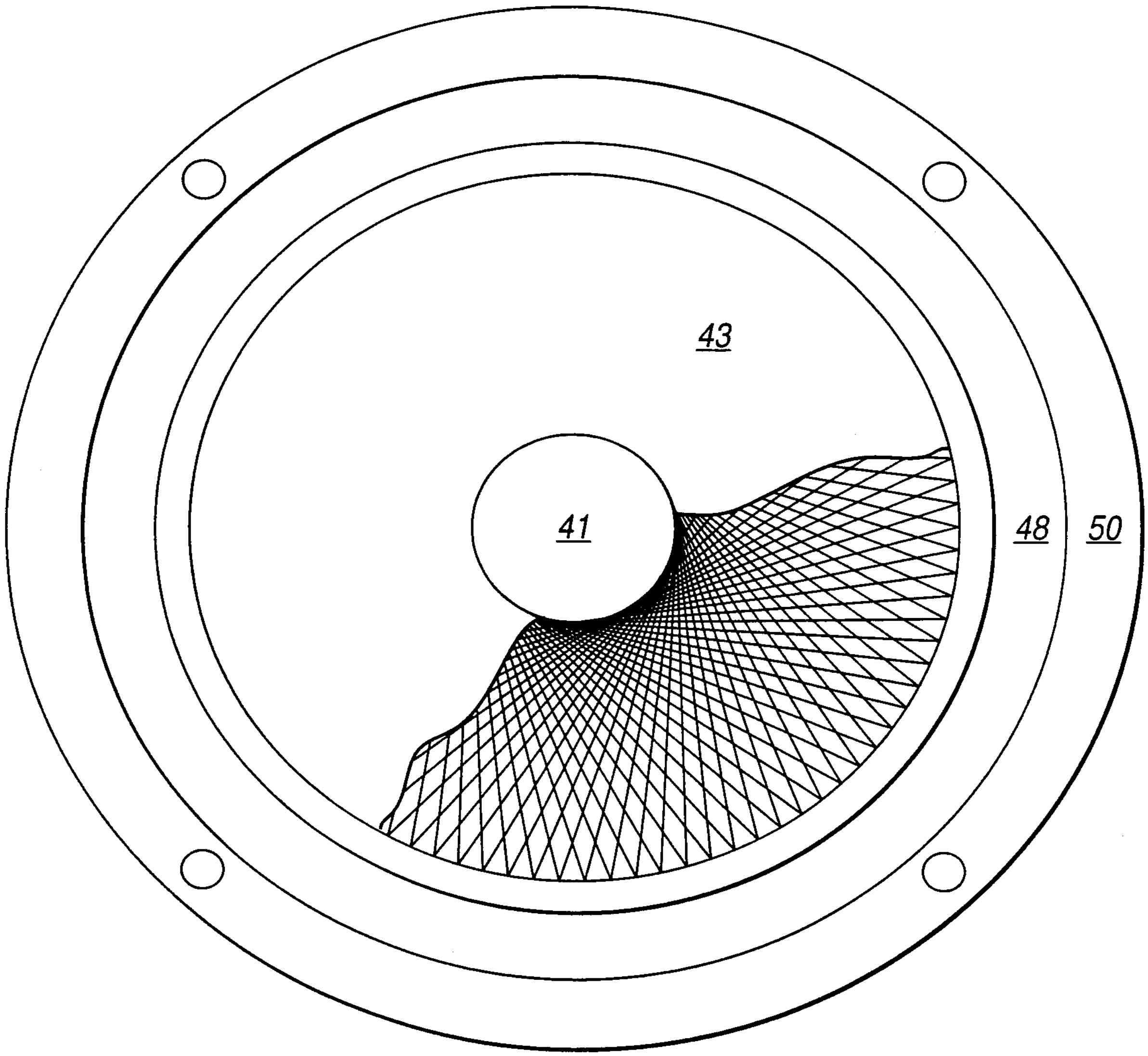

Fig.6

DERWENT-ACC-NO: 2001-475540

DERWENT-WEEK: 200408

TITLE: Stiffened membrane assembly for use as diaphragm of loudspeaker drive unit, has tensile members spanning the frame, producing tension on inner hub and outer rim of frame

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ABSTRACTED-PUB-NO: WO 0078091 A2

BASIC-ABSTRACT:

NOVELTY - The stiffened membrane assembly comprises a frame (2) and several tensile members (3). The tensile members span the frame and comprise cords made of plastics material filaments which act in tension on the inner hub (5) and outer rim (4) of the frame. A membrane to constitute the actual diaphragm is provided on one of conical surfaces of tensile member by bonding it to the tensile member.

DESCRIPTION - INDEPENDENT CLAIM is also included for the following:

(a) Loudspeaker drive unit;

(b) Loudspeaker enclosure

USE - For use as diaphragm of loudspeaker drive unit such as a tweeter or mid range loudspeaker drive unit as well as a loudspeaker enclosure.

ADVANTAGE - Simplifies generation of very high tensile forces

because tensile members comprise flexible material stretched across the frame and at least one length of flexible material is wrapped repeatedly around the frame. Provides strength and rigidity possessed by the type of construction employed in bicycle wheel.

DESCRIPTION OF DRAWING(S) - The figure shows the perspective view of partially completed diaphragm for loudspeaker drive unit.

Frame (2)

Tensile members (3)

Outer rim (4)

Inner hub (5)

CHOSEN-DRAWING: Dwg.1/6

TITLE-TERMS: STIFFEN MEMBRANE ASSEMBLE DIAPHRAGM LOUDSPEAKER DRIVE UNIT TENSILE MEMBER SPAN FRAME PRODUCE TENSION INNER HUB OUTER RIM

DERWENT-CLASS: V06 W04

EPI-CODES: V06-A02; V06-G01; W04-S01E;

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